

without the control. Because any of the embodiments of the invention described above respond to the magnitude of signal in FIG. 11A, the magnitude of asymmetry with the stall controller operating is always substantially less, heuristically meaning that a performance limiting rotating stall cannot appear because the control will open the bleed valve sufficiently to reject the flow disturbance before there are enough revolutions to allow the stall cell to build.

Referring to FIG. 8, a modern high bypass gas turbine aero engine 40 is shown in which the invention can be used. The engine is typically controlled by Full Authority Digital Electronic Control (FADEC) 42. The FADEC controls fuel flow to the engine in a quantity that is a function of Power Lever Advance (PLA) and other engine operating conditions such N1, the speed of the fan 44 and the compressor speed N2. Other parameters such as inlet temperature and ambient pressure may be used to regulate the fuel flow. The engine has a compressor bleed valve 48. It may have several of these valves at different compressor stages. These valves are used for many purposes.

In this particular, application, the engine contains a plurality of static pressure sensors 50 at two axially spaced locations immediately in front of the high compressor. FIG. 9 illustrates a possible layout for these sensors. There 52 identifies the upstream static pressure sensors; 53 identifies the downstream static pressure sensors. The compressor blades (only one rotor blade is shown) are shown as number 54 and are attached to a disk 56. The sensors 28, 29 provide the signals Sa1-San and Sb1-Sbn to a signal processor(SP) 49, which produces the bleed control area signal  $A_{con}$ , which controls the servo controlled bleed valve 48. The signal processor is assumed to contain a computer and associated memory and input/output devices for carrying out control steps shown in FIG. 10, explained below.

It was explained above that the bleed valve opening or area is determined from the magnitude of  $\alpha$  ( $|SFC1|^2$ ) and a value for the annulus average time rate of change of compressor flow  $\delta$  and that, depending on the desired control stability, an additional integral term can be added the control function ( $A_{con}=K_1\alpha+K_2\delta$ ). For instance, FIG. 10 shows an overall block diagram for generating the first two terms as values as V1, V2, from the static pressure arrays and that includes the described integration of the difference between actual and a preselected  $|SFC1|$  and limiting the integration value to a min or max level. The Annulus Average Static Pressures are a function of the outputs Sa1-San and Sb1-Sbn are bandpass filtered at 52. Preferably the range of this filter is on the order of 0.01 to 1 times rotor rotational frequency. The summed output is an indication or manifestation of the time rate of change of mass flow (total flow). To produce the value V2, the above sum is multiplied by the scaling factor K2 at block 53.

The static pressure signals Sb 1-Sbn are used in the SFC Computation block 58 to produce real and imaginary values of SFC1. The SFC value (spatial Fourier coefficient) is computed using well known mathematical techniques to resolve the pressure pattern (e.g. P(0) in FIG. 3A) into its harmonic components, though only the first harmonic component SFC1 is used in this embodiment. The real and imaginary components for SFC1 are applied to a filter 57 to resolve the real R1 and imaginary I1 signals are used to define  $|SFC1|$ . The computation at block 59 determines the value of  $|SFC1|$  which is applied to the summing junction 60.  $|SFC1|$  is summed with the "design" (des) value at block 60 and then summed with a feedback value from K4 at block 62 and then integrated at block 64. The result from the integration at 64 is applied to a min/max limiter 66. The

difference between V4 and V5 is determined at summer 67, the resultant error or difference being applied back after scaling K4 (block 63) to the summer 62, where it reduces the input to the integrator 64, thereby reducing the magnitude of V4 so that the actual value for V4 does not exceed the limit values. This effects the anti-windup function discussed above.

The value V5 is scaled by K3 at block 69 to produce the value V6. The third value V1 that is used to produce the commanded bleed area, is computed from  $|SFC1|$  by squaring that value at function block 68 and scaling it with coefficient K2 at block 70. V1, V2 and V6 are summed at 73 to produce actuator signal  $A_{con}$  for driving the bleed valve 48.

Although the invention has been shown and described with respect to exemplary embodiments thereof, it should be understood by those skilled in the art that various changes, additions and combinations of the features, components and functions disclosed herein may be made without departing from the spirit and scope of the invention.

We claim:

1. A controller for a compressor, characterized by:

first means for sensing fluid flow properties in a fluid flow path around a compressor flow axis to produce first signals that manifest circumferential asymmetry of said fluid flow;

second means for providing a second signal that manifests the time rate of change of the mass flow of said fluid in the flow path;

signal processing means comprising means for a providing a first processor signal from said first signals with a value that manifests the magnitude of said circumferential asymmetry; and for adding said first processing signal with said second signal to produce a control signal; and

third means for modifying said fluid flow as function of the magnitude of said control signal.

2. The controller described in claim 1, further characterized in that said first processor signal manifests the first spatial Fourier coefficient for said circumferential asymmetry.

3. The controller described in claim 2, further characterized in that said first processor signal manifests the square of the first spatial Fourier coefficient for said circumferential asymmetry.

4. The controller described in claim 2, further characterized in that said first means comprises a plurality of static pressure sensors located along the circumference of said flow path.

5. The controller described in claim 3, further characterized in that said second means comprises a total pressure sensor located in said flow path.

6. The controller described in claim 1, further characterized in that said signal processor comprises means for producing a second processor signal that manifests the integral of said first processor signal and for adding said first processor signal, said second processor signal and said second signal to produce said control signal.

7. The controller described in claim 1, further characterized in that said signal processor comprises means for producing a second processor signal that manifests the integral of the difference between said first processor signal and a stored value for said first processor signal and for adding said first processor signal, said second processor signal and said second signal to produce said control signal.

8. The controller described in claim 7, further characterized in that said signal processor comprises means for